

**Eradication and Surveillance of *Caulerpa taxifolia* within  
Agua Hedionda Lagoon, Carlsbad, California  
Third Year Status Report**

**Fall 2002 through Summer 2003**

*Prepared for:*

**Steering Committee of the Southern California *Caulerpa* Action Team**

- ? California Regional Water Quality Control Board – San Diego Region (SDRWQCB)
- ? California Regional Water Quality Control Board – Santa Ana Region (SARWQCB)
- ? California Department of Fish and Game (CDFG)
- ? National Marine Fisheries Service (NOAA-NMFS)
- ? U.S. Department of Agriculture (USDA)

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## **Eradication and Surveillance of *Caulerpa taxifolia* within Agua Hedionda Lagoon, Carlsbad, California Third Year Status Report**

**Fall 2002 through Summer 2003**

### **EXECUTIVE SUMMARY**

On June 12, 2000 the first known infestation in the Western Hemisphere of the invasive strain of the tropical marine alga, *Caulerpa taxifolia*, was discovered in Agua Hedionda Lagoon, in Carlsbad, California. This document reports the results of the third year of the eradication program undertaken by the Southern California *Caulerpa* Action Team (SCCAT). Merkel & Associates has been contracted to conduct the eradication under the oversight of the SCCAT, a broad-based task force assembled from federal and state resource and regulatory agencies, exotic species experts, and marine resource scientists.

During the third year, covering fall 2002 to the end of summer 2003, there was no *C. taxifolia* found in the lagoon. Survey work involved four surveys conducted quarterly. Full surveys of the entire lagoon were conducted in fall 2002 and summer 2003, while the intervening winter and spring surveys were limited to high-risk areas previously known to support *C. taxifolia*. Assessments of the efficacy of the surveys using artificial *Caulerpa* found the surveys to be between 47 and 77% effective. Efficacy was dictated by water clarity and the amount of eelgrass occurring in the surveyed areas.

The third year of monitoring is marked by the completion of all four consecutive surveys with no *C. taxifolia* being found. None has been discovered since September 11, 2002, during the summer survey of 2002 (Year 2). The goal of the current phase of the eradication is to continue conducting surveys throughout the lagoon. The eradication effort will be completed following three years of negative surveys conducted during the high growth seasons.

In the first year of the program, approximately \$1.1 million was spent on eradication at Agua Hedionda Lagoon. In the second year, approximately \$0.8 million was spent, with surveillance expenses being considerably more than treatment. During the third year, approximately \$0.6 million was spent at Agua Hedionda Lagoon, covering primarily expenses for surveillance. A total of approximately \$2.5 million has been spent at the site since June 2000.

## INTRODUCTION

The highly invasive Mediterranean strain of the tropical marine alga *Caulerpa taxifolia* was discovered in Agua Hedionda Lagoon, Carlsbad, California in June 2000 (Figure 1). Its discovery represented the first known occurrence of this strain within the Western Hemisphere and is believed to pose a major threat to coastal ecosystems and recreational and commercial uses dependent upon coastal resources. While the species was also identified at a second site in California (Huntington Harbour, Orange County), the Agua Hedionda Lagoon infestation is the larger of the two known infestations. It is likely that *C. taxifolia* had been in the lagoon for at least four years prior to its discovery. It is not known whether other infestations also exist elsewhere in the United States. The continued wide availability and use of this species by saltwater aquarists is cause for concern.

In the United States, the Mediterranean strain of *Caulerpa taxifolia* has been banned from importation and interstate commerce since 1999 through the Federal Noxious Weed Act. Legislation banning the transport, sale, and possession of nine potentially invasive species of *Caulerpa*, including *C. taxifolia*, was enacted in the State of California in September 2001. Earlier in 2001, the City of San Diego adopted an ordinance with similar restrictions applicable to the entire genus of *Caulerpa*.

Since the discovery of *C. taxifolia* in Agua Hedionda Lagoon in June 2000, eradication, surveillance, public outreach efforts, eradication research, and legislative efforts have been initiated and are on-going. The primary goal of the Southern California *Caulerpa* Action Team (SCCAT), which is made up of resource managers, marine resource and pest control scientists, permitting agencies, marine biological consultants, land-owners and environmental stakeholder representatives, has been on eradication of the known infestations.

Tremendous progress was made during the first two years of the eradication. From the date of discovery (June 2000) until the end of the Summer 2001 survey, the eradication effort at Agua Hedionda Lagoon primarily involved the treatment of all detected *C. taxifolia*. The amount of *C. taxifolia* present in the lagoon at the time of discovery was estimated to be 1,047 m<sup>2</sup> (Merkel & Associates, 2001a). By the end of the second year of eradication efforts at Agua Hedionda Lagoon the amount of *C. taxifolia* discovered had been reduced to 0.4 m<sup>2</sup> (Merkel & Associates, 2003). The location of all *C. taxifolia* discovered since the beginning of the eradication effort is indicated in Figure 1.

This document provides a synopsis of the third year's efforts and costs, and reports on the status of the lagoon and the progress toward the final goal of full eradication of *Caulerpa taxifolia* from Agua Hedionda Lagoon. The third year involved quarterly sampling conducted from Fall 2002 to Summer 2003 (September 2002 to September 2003). Please refer to the Year 1 and Year 2 reports for details on survey and treatment actions completed during those years.





*Caulerpa taxifolia* discovered since June 2000  
Agua Hedionda Lagoon, Carlsbad, CA  
Last find: September 2002

Figure  
1

## ERADICATION PROGRAM- THIRD YEAR: FALL 2002 THROUGH SUMMER 2003

Following the intensive summer 2001 survey and treatment season, a systematic quarterly survey program was undertaken to search for additional patches of *C. taxifolia*. During the second year of the program surveys were conducted lagoon-wide, covering the west, central, and east basin of Agua Hedionda Lagoon. During the third year, surveys were still conducted quarterly, however the winter and spring surveys were reduced to focused surveys of high-risk areas in the lagoon. The invasive strain of *C. taxifolia* has been shown in some studies to stop growing when water temperatures drop below 15°C (59°F), with frond growth resuming when the water warms back up to 17-18°C (63-64°F) (Komatsu et al. 1997, Thibaut 2002). The coldest water temperatures were seen at Agua Hedionda Lagoon during early winter, beginning in late December 2002 continuing to mid-February 2003. Water temperature during this period generally ranged between 14 and 15°C (57-59°F), with a low of 13.5°C (56.3°F) in late December 2002. Due to the low water temperatures and in an effort to conserve limited fiscal resources, the Winter 2002 and Spring 2003 survey efforts were limited to areas previously known to support *C. taxifolia*.

### METHODS

All surveys used the laid-transect line method. This method employs the use of SCUBA divers swimming along transects lines deployed by a small boat using differential GPS. The divers use a guide-line to maintain their spacing at 1 meter apart, and vary their swimming speed based on visibility and density of eelgrass. Having tested a variety of other survey methods, including towed divers, towed cameras, and laser line scan, it appears that the most effective approach to conducting intensive surveys that can locate very small fronds of *C. taxifolia*, even within dense eelgrass beds, is the current method employed. This survey intensity is defined as an eradication level survey in which divers are used to make visual searches to ensure 100% viewing of the study area (NMFS, 2002).

An exception to this method occurred in the Snug Harbor portion of the east basin of the lagoon. Shortly after the original discovery of *C. taxifolia* growing Snug Harbor in June 2000, a survey grid made of rope was immediately deployed over what was believed to be the extent of the infestation. This grid had numbered and lettered axes that allowed for systematic, repeatable surveys and facilitated mapping of, and return to, discovered *C. taxifolia* for treatment. This grid remained in place for half of the third year and was surveyed also by SCUBA divers as part of regular quarterly surveys. In past years the results of grid surveys were tracked separately from lagoon-wide surveys because this allowed for simple tracking of temporal and spatial changes in *C. taxifolia* distribution. However, as surveillance efforts began to find the grid to be free of *C. taxifolia* and as access and safety issues arose, it became necessary to re-assess the usefulness and necessity of maintaining the grid. In order to facilitate public access to the grid area in Snug Harbor as well as ensure user safety, the rope grid was removed in January 2003. Its position was recorded with dGPS, in order to allow the plotting of any *C. taxifolia* found there in the future, if necessary.

Although *C. taxifolia* was not detected during the third year, survey staff remained trained and prepared to respond to new discoveries. If *C. taxifolia* were to be found by divers, its location would be recorded by dGPS and the patch assessed by a biologist. The dimensions and, if

possible, the number of fronds, number and length of thalli, and typical frond lengths would be recorded for each patch located. The patch would be marked by colored pin-flags to be left in place during treatment in order to relocate the treated *C. taxifolia* at a later date if necessary for efficacy investigations. The *C. taxifolia* would be contained within 24 hours with a PVC tarp and treated with solid chlorine pucks, as outlined in the Revised Eradication Plan for *Caulerpa taxifolia* in California (Merkel & Associates, 2001b).

Several times during the eradication effort assessments were made of the efficacy of the survey methodology. This was achieved through the placement of artificial *C. taxifolia* in the lagoon during the survey. The amount of plants found by the team was analyzed based on water clarity, plant size, and density of eelgrass in the survey area. These trials allowed for a rough assessment of the confidence in the results of the survey for real *C. taxifolia*. They also allowed for the calculation of the number of additional surveys that would be needed to achieve an acceptable level of confidence that all *C. taxifolia* present in the lagoon had been found. The full results and discussion of these trials were detailed in *Caulerpa taxifolia in Southern California: Results from Survey Efficacy Trials* (M&A 2004). Efficacy trials were undertaken during the Fall 2002 and Summer 2003 survey.

Water temperature was monitored all year at four infested areas in the east basin of Agua Hedionda Lagoon. Data were collected hourly by deployed loggers manufactured by Onset®, with an accuracy of  $\pm 0.2$  °C ( $\pm 0.3$  °F).

## RESULTS

The results of each of the four quarterly surveys at Agua Hedionda Lagoon, conducted during each calendar season, are discussed below. Figure 2 displays the lines surveyed during each quarter of the third year.

### *Fall 2002*

The Fall 2002 survey effort was conducted from mid-September to mid-December 2002. Fall is the season when *C. taxifolia* would be expected to be at its greatest extent and size, therefore a full survey of all basins of the lagoon was undertaken. The grid in Snug Harbor was surveyed using the method of searching each cell individually. The remainder of the lagoon was surveyed using the laid line method with divers at 1-meter spacing (Figure 2).

No *C. taxifolia* was found in the lagoon during this survey.

Two survey efficacy trials were conducted during this period: one in Snug Harbor and one further east near Bristol Cove. The trial in Snug Harbor was intended to characterize survey conditions of good visibility and dense eelgrass. During this trial 77% of the artificial *C. taxifolia* placed in the study area was found by the survey team. The second trial was conducted off Bristol Cove, where visibility is typically poor and eelgrass is sparse. A total of 47% of the



1. Fall  
2002



2. Winter  
2002



3. Spring  
2003



4. Summer  
2003



**Transects Surveyed for *Caulerpa taxifolia* During Year 3 of Eradication Effort**  
**Fall 2002 - Summer 2003**  
**Agua Hedionda Lagoon, Carlsbad, CA**

Figure  
2



artificial *C. taxifolia* placed in the study area was found by the survey team. The results of these trials suggest that between 4 and 7 additional negative surveys would be necessary to be 99% certain that no single *C. taxifolia* patch remains (M&A 2004).

The mean water temperature during the Fall 2002 survey was 17.2°C (62.9°F), ranging between 14.4 and 21.4°C (58.0-70.6°F).

### **Winter 2002**

Due to the low water temperatures, the Winter 2002 survey effort was limited to areas previously known to support *C. taxifolia* (Figure 2). This survey was conducted from January 2 to 17, 2003, and included a full survey of the grid as well as a laid line survey of all areas where *C. taxifolia* has been previously found, plus a 5-meter buffer. This work was conducted in Snug Harbor and at the five other infested areas in the east basin. No survey work was done in the west and central basins.

No *C. taxifolia* was detected in the surveyed areas.

The mean water temperature during the winter 2002 season was 15.6°C (60.1°F), ranging between 13.5 and 19.2°C (56.3-66.6°F).

### **Spring 2003**

Due to a continuing scarcity of eradication funds and the reduced probability of *C. taxifolia* actively growing and spreading during months of lower water temperatures, the Spring 2003 survey was also reduced to cover only areas previously known to support *C. taxifolia* (Figure 2). As an added measure, the buffer area was expanded to 50 meters.

The Spring 2003 survey was conducted from March 31 to June 25, 2003. For safety, public use, and survey efficiency reasons, the survey grid in Snug Harbor was removed prior to the survey. Therefore all areas were surveyed using the laid line methodology.

No *C. taxifolia* was detected in the surveyed areas.

The mean water temperature during the spring 2003 season was 18.1°C (64.5°F), ranging between 15.0 and 21.5°C (58.9-70.8°F).

### **Summer 2003**

The Summer 2003 survey was conducted from June 26 to September 22, 2003. The entire lagoon was surveyed using the laid line methodology, with the exception of a portion of the west basin that was not surveyed (Figure 2). This area had been very recently dredged by Cabrillo Power LLC, and surveyed for *C. taxifolia* in support of requirements outlined in the *Caulerpa* Control Protocol (NMFS 2002). The SCCAT decided that the deeper, recently dredged areas did not need to be surveyed.

No *C. taxifolia* was found in the lagoon during this survey.

Two survey efficacy trials were conducted during this period: one in Snug Harbor and one further east near Bristol Cove. During the Snug Harbor trial, 55% of the artificial *C. taxifolia* placed in the study area was found by the survey team. During the trial conducted off Bristol Cove, a total of 52% of the artificial *C. taxifolia* placed in the study area was found by the survey team. The results of these trials suggest that between 6 or 7 additional negative surveys would be necessary to be 99% certain that no single *C. taxifolia* patch remains.

Water temperature during the Summer 2003 survey ranged between 18.1 and 24.7°C (64.6-76.5°F), with a mean of 22.0°C (71.5°F).

## **TREATMENT EFFICACY**

As discussed in the second year report, an assessment to investigate the efficacy of the treatment methodology of tarping and chlorinating was initiated in April 2002. Openings were cut into selected tarps of various ages and monitored for regrowth of *C. taxifolia*. Since that time no regrowth of *C. taxifolia* has been observed in any of the study plots. Each plot continues to be monitored both for *C. taxifolia* regrowth and for recovery of native species to the exposed bottom. A separate report on this project will be prepared when the study is complete.

## **ERADICATION STATUS**

The encouraging results seen during the second monitoring year persisted throughout the third year, with no *C. taxifolia* found during any of the four surveys. It was anticipated that any small patches that were missed during previous surveys would grow to larger, more easily detectable sizes by favorable environmental conditions during continuing surveys. As explained in the Year 2 report, it was estimated that 1,076 m<sup>2</sup> of *C. taxifolia* was present lagoon-wide at the start of the eradication effort (summer 2000). This amount declined steadily throughout the eradication effort, with only 0.4 m<sup>2</sup> found lagoon-wide in summer 2002 (Figure 3). All surveys since summer 2002 have detected no *C. taxifolia*.

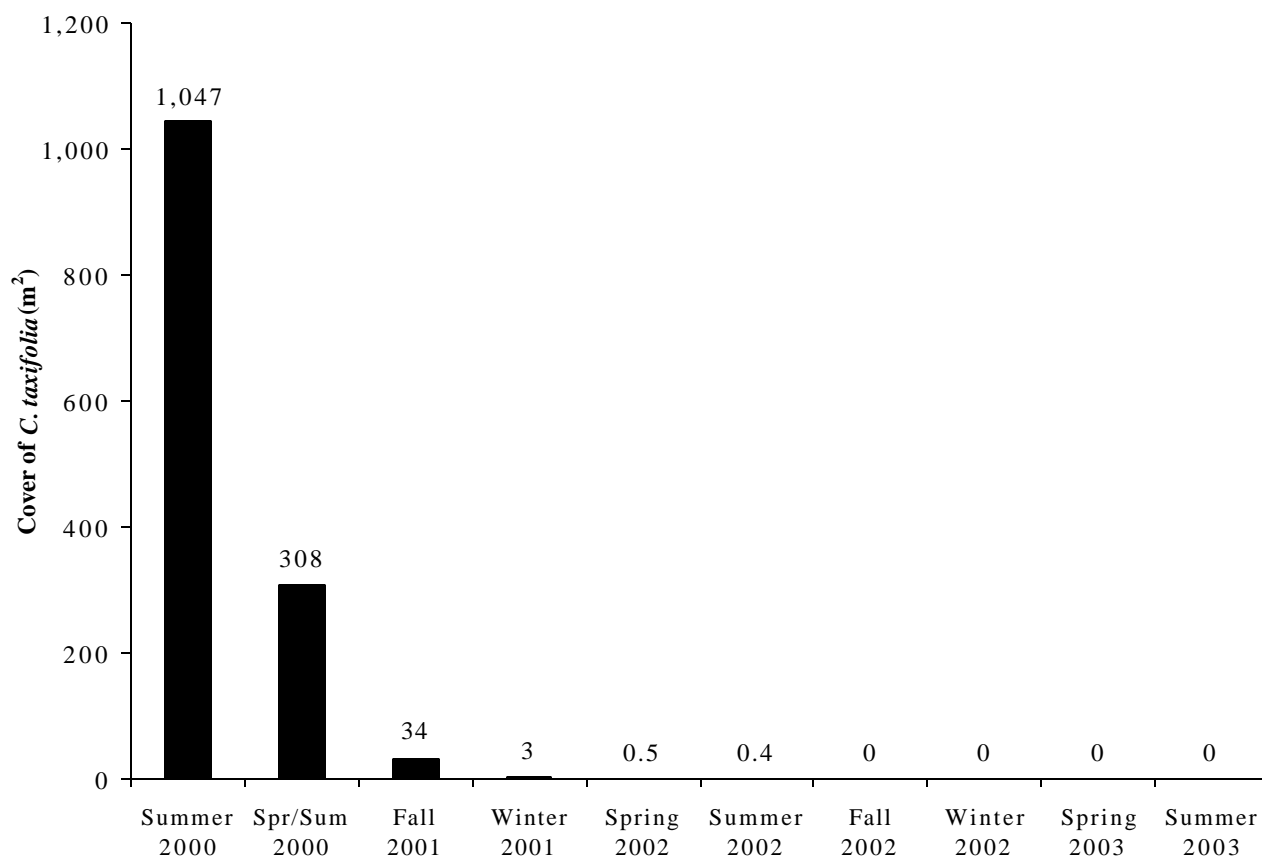


Figure 3. Areal coverage of *Caulerpa taxifolia* in Agua Hedionda Lagoon in square meters.

At the SCCAT Technical Subcommittee Meeting held in April 2003, draft guidelines for declaration of eradication were developed by SCCAT members, researchers, and experts in the field of pest management. The criteria for eradication were based on both the biology of *C. taxifolia* and the capabilities and efficacy of the survey team. The proposed schedule involved conducting surveys for a minimum of two growing seasons (summer and fall) following the last find of *C. taxifolia*. If no *C. taxifolia* were found during the first season, surveys during the second season would be expected to find any patches previously missed, due to patch expansion facilitated by the favorable growing conditions that exist for much of the year in the lagoon. If these surveys conducted over two full growing seasons found no *C. taxifolia*, then surveys would be conducted for one additional growing season (summer and fall) to insure the success of the eradication effort.

Also supporting this approach are the findings of the survey efficacy trials, which found that, based on typical efficacy rates, between 4 and 7 consecutive negative surveys would be necessary to be 99% certain that no single *C. taxifolia* patch had been missed (Merkel & Associates 2004).

## STATUS OF THE LAGOON AND COORDINATION WITH LAGOON USERS

During the third year, activities on the lagoon continued to be coordinated through the Interim Management Plan (Plan), a document drafted and adopted by the SCCAT, the Agua Hedionda Lagoon User Representatives, and the City of Carlsbad. This plan partitioned the lagoon into management units and established safety guidelines for both the eradication crew and recreational users of the lagoon. To coordinate the activities of all users, informational signage at access points around the lagoon was posted with regular activity updates, and a recorded phone message with schedule updates was maintained. This Plan allowed the survey work to be conducted more safely and efficiently than before the adoption of the plan. The City of Carlsbad and SCCAT review the Plan several times annually to assess its efficacy.

The first version of the Plan originally adopted in June 2002 included the following restrictions on the lagoon relating to the control of *C. taxifolia*: a ban on anchoring and fishing throughout the east basin, a prohibition of wake height by boats in excess of 0.3 m (12 inches) when measured from the undisturbed water surface to the top of crest, and continued exclusion of all unauthorized vessels from most of Snug Harbor, the most infested area of the lagoon.

As promised by the SCCAT, these restrictions were reviewed regularly in the context of the progress of eradication efforts. In November of 2002, SCCAT recommended the re-opening of the eastern portion of the east basin to fishing, given that after two years of survey, no *C. taxifolia* had ever been found there. The following year, in May 2003, SCCAT also recommended that the previously closed area in Snug Harbor be opened to passive use vessels (non-motorized vessels). The Carlsbad City Council approved and adopted both of these changes. SCCAT will continue to regularly revisit the Plan with the goal of eventually recommending the return to pre-*C. taxifolia* uses.

With the Plan, the SCCAT has attempted to facilitate the safe and effective eradication of *C. taxifolia*, while minimizing the impact to recreational users of Agua Hedionda Lagoon. In order to assess the number of users affected by the use modifications, a use-log was kept by eradication support staff. During the summer and fall months of 2002, a record was kept of the number and type of vessels using the lagoon each hour, including passive vessels, personal watercraft (jet-skis), and power boats. In June 2002, there were between 0 and 3 vessels using the lagoon each hour during the day, in July 2002 there were between 0 and 6, in August 2002 there were between 0 and 4, and in September there were between 0 and 3. These figures only reflect use per hour, not the total number of different users each day. While these figures also do not capture the amount of users that chose not to visit the lagoon due to the restrictions, they do suggest the order of magnitude of the potential impact. It is likely that less than ten vessels were affected daily by the use re-alignments and restrictions.



## ERADICATION COSTS

During the third year of the eradication program at Agua Hedionda Lagoon, Merkel & Associates performed many tasks, including SCCAT coordination and presentations, outreach, surveillance and mapping, maintenance of *C. taxifolia* stock from Agua Hedionda Lagoon, collection and management of data relating to efficacy of treatment and survey efforts, reporting, and a variety of other tasks as assigned. The vast majority of the funds expended were for the surveillance work. During the third year (September 2002 – September 2003), approximately \$600,000 was expended on the above-described work. This funding was provided by the State Water Resources Control Board, the California Department of Fish and Game, and NOAA Fisheries. In addition, funding was provided by the Agua Hedionda Lagoon Foundation through grants from the FishAmerica Foundation (funded by the NOAA Restoration Center) and from the NOAA Community-Based Restoration Project. Since June 2000, eradication efforts at Agua Hedionda Lagoon have cost approximately \$2.5 million.

Additional costs of eradication not accounted for above include the contributions of all active SCCAT members including the California Department of Fish and Game, NOAA Fisheries, the San Diego and Santa Ana Regional Water Quality Control Boards, U.S. Department of Agriculture, UC Davis, University of California Cooperative Extension, the City of Carlsbad, Agua Hedionda Lagoon Foundation, and Cabrillo Power.

## FUTURE ACTIONS IN THE ERADICATION PROGRAM

Continued intensive surveys seeking the detection of any new patches arising from small, previously undetected fragments will be the focus during the fourth monitoring year (fall 2003-summer 2004). There will be a Fall 2003 and Summer 2004 survey conducted in the fourth monitoring year. If *C. taxifolia* is encountered in either of these surveys, the timetable to eradication success will be reset, with the three years of follow-up surveys re-initiated following the treatment of the discovered *C. taxifolia*.

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